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ABSTRACT

The purpose of this exploratory study was to examine the effectiveness of learner manipulation of visuals with and without organizing cues in computer-based instruction on adults' factual, conceptual, and problem-solving learning. An instructional unit involving the physiology and the anatomy of the heart was used. A post-test only control group design was applied with 74 undergraduate subjects from a large eastern university. Subjects were randomly assigned to one of three treatment groups: learner generated with cued visual organization; learner generated with uncued visual organization; and control (system-provided organization). The dependent variables measured the subject's ability to identify individual parts of the heart using visual cues; retain facts and definitions; reproduce key information; and utilize the information for problem solving. The results showed that in no case were the scores on either treatment group involving manipulation of visuals greater than the control group which provided the visuals. (Contains 30 references.) (Author/JLB)

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Title:

The Effects of Varied Visual Organizational Strategies within Computer-Based Instruction on Factual, Conceptual and Problem Solving Learning

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Abstract

The purpose of this exploratory study was to examine the effectiveness of learner manipulation of visuals with and without organizing cues in computer-based instruction on adult's factual, conceptual and problem solving learning. An instructional unit involving the physiology and anatomy of heart was used. A posttest-only control group design was applied with 74 undergraduate subjects from a large eastern University. Subjects were randomly assigned to one of three treatment groups -- Learner Generated with Cued Visual Organization, Learner Generated with Uncued Visual Organization and Control (System-Provided Organization). The dependent variables measured the subject's ability to identify individual parts of the heart using visual cues, retain facts and definitions, reproduce key information and utilize the information for problem solving. No differences were found between the Control and the Learner-Generated Groups. For the problem solving measures, the Learner-Generated with Cued Visual Organization group scored significantly higher than the Uncued Visual Organization group. Subjects in the control group also scored significantly higher than the Uncued Visual Organizational group for problem solving. In post hoc comparisons, trends were found with the Cued Visual Organizational group scoring significantly higher than the Uncued Visual Organizational group for the identification, problem solving and drawing measures.

INTRODUCTION

Technological advances have evolved computer-based instruction into an increasingly visual and engaging learning system. With these advances, new strategies of presenting information within computer-based media have emerged. The graphical user interface of current computer technology and development software allow for the manipulation and movement of visual elements. Providing opportunities for active learner manipulation of visual elements on the screen may demonstrate and encourage generative processing of information. But, is the mere manipulation of visuals sufficient to increase cognitive processing or should some type of cueing strategy be provided so that the learner can actively construct visuals into a meaningful arrangement? Theoretically, generative learning strategies support this notion. Generative learning strategies have shown that interaction with and selective attention to sensory information may establish links to memory in constructing meaning (Wittrock, 1974a, 1974b, 1990).

Manipulation of individual visual elements may be more effective when learners create their own visual organization versus an organization or cued visual structure provided by the system. Activities to encourage learner's organization or ordering of the information can activate the encoding process which builds connections between thoughts, develops a cognitive organization for them and integrates relevant information in working memory with a learner's prior knowledge (Weinstein & Mayer, 1984).

Empirical evidence to support the use of a learning strategy for manipulating individual visual elements onto an organizational framework in CBI is lacking in the literature. Numerous studies exist involving the use of visuals within instruction (e.g., Dwyer, 1978; Guttman, Levin & Pressley, 1977; Levin, 1986). However, the manipulation of visual elements with and without organizational cues in computer-based instruction is an instructional strategy only recently possible through current technology, and was investigated in this study.

Visuals

The use of visuals within instruction has been the subject of a large body of research over several decades. Many studies conducted with children have dealt with the recall of information from illustrations that support aural or print instruction (e.g., Guttman, Levin, & Pressley 1977; Levin, 1986). Levin (1989) has concluded from this accumulated literature that pictures presented in conjunction with text improve comprehension and memory over information presented by text alone.

Related to this body of research, Guttman, Levin & Pressley (1977) conducted a study involving oral prose and visuals. After reading a story, they presented visuals with missing pertinent information (or partial pictures) to kindergartners. Contrasting this treatment with the presentation of the complete visuals, the experimenters found that the incomplete pictures did not have an effect on learning. The presentation of incomplete visuals devoid of critical content may be more powerful through the construction of a visual organization.

The manipulation and organization of visuals has been examined through the illustration of stories with cutout characters. Lesgold, Levin, Shimron, and Guttman (1975) conducted a series of experiments to examine the potential benefits of pictorial elaboration with young children. Interestingly, the researchers found that experimenter-constructed illustrations provided significantly improved acquisition of information in comparison with learner-constructed illustrations. The construction of the cutout figures by the experimenters may have provided a type of organization not

present when the children constructed their own representations. These results suggest a possible connection between experimenter-provided organization of visuals and increased cognitive processing.

Levin, Anglin and Carney (1987) conducted a meta-analysis of these studies involving prose learning and visuals. Based on this review, recommendations were formulated concerning the use of visuals within prose instruction. One principle presented includes that the function of visuals or pictures should be based on the needs of the learner, the instructional objectives and materials used. Reiber (1994) interprets this principle suggesting that the ".... the function of any visual must be consistent with its intent" (p.141). Recommendations such as these point toward the essential role of visuals within instruction and that caution must be taken that they not detract from the content and serve a functional purpose for learning.

Visuals and Computer-Based Instruction

In contrast to studies conducted with visuals and text, recent investigations involving visuals within computer-based instruction is a fairly unexplored area. In response, Park (1991) has called for an increased research effort concerning the appropriate selection of information-representation forms for instructional computing. Existing research has included comparisons involving visual presentation modes (Calvert, Watson, Brinkley & Penny, 1990), static vs. dynamic display of graphical information (King, 1975) and the use of animation within instruction (Reiber, 1990). The results of these studies were mixed and involved various conditions of presentation mode, levels of learning and findings. McCuiston (1991) found that the use of dynamic visuals within a college-level computer-assisted lesson on descriptive geometry concepts facilitated spatial ability skills, but did not increase content acquisition. The college students scoring in the lower 25% of the content acquisition test who viewed static visuals achieved higher scores than those who viewed a dynamic presentation. These conclusions, however, are based on computer manipulation of visuals and cannot be extended to the learner manipulation of visuals.

Visuals and Cueing Strategies

Dwyer (1978) has also substantially added to the literature by investigating the use of visuals and expository text within instruction. He maintains that for optimal learning to occur with visualized instruction, the learner must be able to "...locate, attend to, and interact with the relevant instructional stimuli while ignoring or minimizing the effect of the competing irrelevant stimuli" (Dwyer, 1978, p. 156). Cautioning against the use of complex or realistic of visuals within instruction, Dwyer advocates the use of cueing to highlight the essential information from other types of stimuli. Reviews of these studies conclude that visual presentation of information should attract and sustain the learners attention without adding unnecessary attention-gaining devices that may impede learning. These conclusions suggest that involving the learner with the visual (i.e., by selecting and moving it) may optimize learning.

The use of visual cueing strategies has also been shown to be effective within computer-based instruction. Canelos, Dwyer, Taylor, Belland, and Baker (1989) found the use of imagery cues and attention directing strategies to be effective with adult learners. Presentation modes and cueing, as well as the use of partial pictures and system provided organization of visuals have been shown to be important instructional strategy variables to be considered in the design of visual instruction.

Generative Learning Theory

The generative process of learning holds that it is necessary for the learner to have an active, participatory role within the instruction in order to construct and interpret

individual meaning of information. Wittrock's (1974a, b) construct of generative learning defines the purpose of learning as the generation of abstract and distinctive, concrete associations between prior experience and incoming stimuli. Research in this area has primarily been carried out with textual information such as word lists, word pairs, sentences, headings, word problems (e.g., Wittrock, 1990; Wittrock & Carter, 1975), but has also included some studies involving visual elements.

Linden and Wittrock (1981) taught children to generate interpretations of paragraphs and create images relating sentences to one another. In addition, children were taught to generate relations between stories they read and their own experience. With time held constant, the results indicated about a 50% increase in comprehension attributed to the generative activities (Linden & Wittrock, 1981). In a related study with 5th grade students, Bull and Wittrock (1973) found that drawing pictures of vocabulary words enhanced recall of definitions among the subjects one week later. Mode of generation did not seem to be the primary factor in these studies. The important variable, however, was the encouragement and facilitation of processing by the learner. The learning environment should facilitate some type of generation within the learner. Generating relationships between the parts of the information may build stronger connections in the learner's mind compared to simply reading the material.

Direct Manipulation and Organizational Strategies

Generative activities can include various types of interaction with instructional content including paper and pencil activities, and manipulating concrete objects (Bull & Wittrock, 1973; Bennett, 1991). Current computer technologies are also well-suited to providing generative experiences through the direct manipulation of on-screen visuals. Direct manipulation refers to a type of computer interface in which learners use a mouse to manipulate spatially organized objects on the screen (i.e. click and drag) (Whiteside, Wixon, & Jones). This type of interface may potentially contribute to learning. Schneiderman (1992) contends that physical, spatial, or visual representations of information appear to be easier to retain and manipulate than textual or numeric representations. Carrol, Thomas and Malhotra (1980) found that students who manipulated spatial representations were faster and more successful in problem solving than subjects given similar problems without spatial representation.

The direct manipulation of computer visuals by the learner must incorporate an instructional purpose in order to constitute a viable learning strategy. The movement of visual elements toward an intentional goal is a strategy to involve the learner for the purpose of increasing cognitive processing. Learning strategies assist the learner in selecting, acquiring, constructing and integrating new information (Weinstein & Mayer, 1986). Organizational learning strategies include ordering or grouping items which activate two parts of the encoding process --construction and integration. Construction involves a process that builds connections between thoughts and develops a cognitive organization for them, while integration includes connecting new information with prior knowledge (Weinstein & Mayer, 1984; 1986). Learner manipulation of on-screen elements into a target visual organization may support the learner in the process of connecting information about the individual visual items to other items in long term memory. Jonassen (1988) states that organizational learning strategies can assist in the structuring and restructuring of the learner's knowledge base by clarifying how the concepts relate to one another.

PROBLEM STATEMENT

The purpose of this study was to explore how the active, spatial manipulation of visual elements by the learner and the placement of them into an organizational framework

can assist in increased cognitive processing and achievement. Specifically, this research drew upon generative processing theory to investigate the effects of two forms of visual organizational strategies (cued and uncued) on four types of learning objectives. It was hypothesized that those who participated in the cued and uncued organizational treatments would become more engaged in the content and would achieve significantly higher scores on the posttests than the control group. It was also hypothesized that those students in the uncued organizational treatment group would require a higher level of attention and cognitive processing and thereby recall more facts and concepts and solve more problems than those who were provided a cued organization.

METHOD

Subjects

This study involved 74 volunteer college students enrolled in an undergraduate statistics course at a large eastern university. Individuals were randomly assigned to one of the three treatment groups. No attempt was made to group the subjects by ability or reading level, however, previous knowledge of human physiology was assessed prior to instruction.

Materials

The content of the lesson used in this study was adapted from paper-based text materials (2000 words) developed by Dwyer and Lamberski (1977) concerning the physiology and function of the human heart. The lesson includes factual, conceptual and problem solving information covering the parts of the heart, circulation of blood, cycle of blood flow and blood pressure. The basic lesson was re-created in a computer-based instruction format programmed using Authorware Professional for the Macintosh. A pretest consisting of 36 questions on the basic physiology of the human body was initially given to the students to assess the effect of prior knowledge on posttest scores.

Instructional Treatments

Three treatments were developed for this study which contained identical instructional content while varying the levels of manipulation and visual organizational cueing.

Learner-Generated Cued Visual Organization. Subjects in the Cued Visual Organization group were required to move (click and drag) a visual graphic of a part of the heart from the left side of the screen onto a frame of the whole heart containing tan outline of the primary parts. This outline served as an organizational guide for the correct placement of the visuals (see Figure 1). Subjects received instructions to place the part in its correct location on the outline of the heart. A pre-lesson exercise was provided to familiarize subjects with mouse control and to allow for practice with the manipulation and placement of visuals.

No text was presented prior to the movement, forcing the learner to first locate the correct position on the heart. After successful placement of the part, textual information describing the part, its location, function and/or relationship to other parts of the heart appeared next to the visual. If the part was not placed correctly, it would automatically return to its original position in the left hand corner of the screen, providing animated negative visual feedback. The subject was required to place the visual again until correct.

Insert Figure 1 about here

Learner-Generated Uncued Visual Organization. The Learner-Generated Uncued Visual Organization treatment group utilized a similar strategy. After an identical pre-lesson exercise, the Uncued Organizational treatment group was required to move the parts of the heart onto a frame of the whole heart containing no outlined visual organizational guide concerning the parts' location. As the lesson progressed, the visual of the heart was constructed part by part encouraging the learner to actively build the visual connections from the parts, their location and their function within the heart to the textual information (see Figure 2). As in the Cued Visual Organization group, when not placed correctly, the part would automatically return to its original position on the screen and the lesson would not advance. As with the Cued Organization, after successful placement of the part, textual information describing the part, its location, function and/or relationship to other parts of the heart appeared next to the visual.

Insert Figure 2 about here

Control (System-Provided Entire Visual). The control group presented the lesson content via text and graphics in a page-turning format with no learner manipulation of visuals. Subjects viewed graphics with specific parts of the heart highlighted and their corresponding textual information. The only action required by the learner was proceeding to the next frame.

Dependent Measures

The posttest was a pencil and paper test consisting of a total of 90 questions measuring different types of educational objectives. The identification test consisted of twenty multiple-choice items requiring students to identify numbered parts on drawings of the heart. The terminology test consisted of twenty multiple-choice questions designed to measure knowledge of facts, terms and definitions. The comprehension test consisted of twenty items and tested the ability of the student to use the information to explain another phenomenon occurring simultaneously. The drawing test required students to reproduce a diagram of the heart and place numbers of the twenty parts in their correct positions measuring the student's ability to construct, and/or reproduce items in their appropriate context. Finally, a problem solving test of ten multiple choice questions tested the students' ability to transfer understanding of the information and to solve problems related to the content. The following reliability coefficients (KR-20) were recorded for each of the tests: .93 total test, .82 Identification, .79 terminology, .80 comprehension, .83 Drawing, and .583 problem solving. A paper and pencil pretest was also conducted prior to the instruction. The pretest consisted of 36 questions on human physiology.

Procedures

The study was conducted in one of the University computer labs. As the students arrived they were randomly assigned to one of three treatment groups. After a brief presentation, the students individually took the pretest followed by the instruction. Upon completion of the instruction, the posttests were immediately administered in the following succession: drawing, identification, terminology, comprehension and problem-solving tests. Individualized instruction was conducted via computer while the pretest and final testing were delivered in traditional, paper and pencil format.

Research Design and Data Analysis

This study encompassed a post-test only control group design controlling for prior knowledge. The variables manipulated were learner-generated manipulation of visuals with cued organization and learner-generated manipulation of visuals with uncued organization and control (system-provided organization).

Separate one way analysis of covariance (ANCOVA) was used to test for significant differences among the three groups for each criterion measure: drawing, terminology, identification, comprehension, problem solving and total test. A .05 alpha level was selected to determine significance among the three treatments. Due to the exploratory nature of this study, post hoc comparisons were conducted to analyze the differences between groups for all measures.

RESULTS

Descriptive results for achievement showing the means adjusted for prior knowledge are reported in Table 1. Total score approached overall significance $p>.05$ ($F(70,2)=3.10$, $MS=288.74$, $MSE=93.15$). Examining the subscores revealed a significant effect for problem solving $p<.05$ ($F(70,2)=3.58$, $MS=12.49$, $MSE=3.49$).

Since the means for the cued visual group were higher for each dependent measure, exploratory post-hoc comparisons were run between groups for each. Based on this data, an interesting trend was discovered. For the identification, problem solving and drawing tests, the cued visual treatment scored significantly higher than the uncued visual treatment, but not significantly higher than the control group. For problem solving, the control group also scored significantly higher than the uncued group. The remaining two tests, comprehension and terminology were not significantly different at $p=.068$, 063, respectively.

DISCUSSION

This exploratory study investigated the relationship of the direct manipulation of visual elements toward an organizational framework, providing varying levels of cued information and achievement on four types of learning objectives. The results suggested some interesting conclusions. Of primary importance was that fact that in no case were the scores on either treatment group involving manipulation of visuals significantly greater than the control group which provided the visuals. These results, although theoretically somewhat unfounded, support the findings of Lesgold, Levin, Shimron and Guttman (1975).

Although it was expected that the manipulation of visual elements would be more effective, especially when learners created their own organization, this hypothesis was not supported. Learner-generated uncued visual organization was perhaps too cognitively demanding thus exerting a detrimental effect on achievement. Given no visual structure, the students expressed difficulty inferring the locations of the parts of the heart. The majority of their cognitive processing, therefore, may have been utilized by unstructured guessing, leaving very little attention available to associate textual information with the visual.

The second interesting and important finding of this study, supports the inclusion of visual cues when incorporating a generative learning strategy. In post hoc comparisons for three of the dependent measures (Identification, Problem Solving and Drawing), the cued visual organization group scored significantly higher than the uncued visual organizational group. These results lead to some interesting speculation. When little or no information is

provided in a generative strategy, learners may become frustrated and inattentive (reverting to trial and error guessing) when required to make a specific right or wrong response. The learner cannot construct his or her own organization since a specified one is already expected. The generative nature rests solely in the movement, but not the placement of the visual. With the system cues present, locating the visual may have reduced frustration and enabled the learner to concentrate on the part's label and location.

Another speculation regarding these findings is related to the three types of dependent measures which were significant. The generative activity required the learner to move visuals which were labeled onto a framework, closely representing the cognitive processing required on the tests. The most interesting finding was the impact of this activity on problem solving. Upon closer examination of the problem solving questions, it became quite evident that without being able to identify the parts mentioned (i.e., right atrium, tricuspid valve, vena cava, etc.), the learner would not be able to understand the question. While not directly supporting the notion that generative learning or cueing enhances problem solving, it does support the learning of prerequisite knowledge necessary for problem solving.

While the generative nature of manipulating the visuals showed no significant main effect, the combination of this type of activity and a cued organizational framework displayed an interesting trend. This strategy supports strengthening the organizational cues when combined with the manipulation of visuals. In each case, means were higher for the cued organization, although not significantly, than the control. The combined strategy points toward a potentially integrated generative strategy through which the learner interacts with sensory information. Manipulating the part in addition to targeting a visual structure may provide a cueing strategy and assist the learner in cognitively organizing the information.

This study, while exploratory in nature, provided valuable information in regard to the generative manipulation of visual elements into an organizational framework. Distinct from traditional system-provided animation, this strategy capitalized on the direct manipulation interface capability of authoring software. Yet researchers and designers must consider the effects of this strategy on learning and further research questions remain. How much visual organizational cueing is necessary in combination with manipulation to encourage optimal cognitive processing by the learner? Should textual information be given prior to the movement of the visual so that learners are provided with more information with which to organize the visuals? Should the learner create his or her own organization without a framework or outline, based on previously presented textual information? What other factor may be potentially masking the generative effect? The results and positive trends found in this study warrant further research in the area of learner-generated manipulation of visuals and cued organizational frameworks.

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Table and Figure Captions

Figure 1. Learner-Generated Cued Visual Organization (SEE APPENDIX C)

Figure 2. Learner-Generated Uncued Visual Organization (SEE APPENDIX C)

Table 1. Adjusted Means and Standard Deviations

Table 2. Analysis of Covariance

Table 3. Significance Levels Post-Hoc Comparisons

Table 1
Adjusted Means and Standard Deviations

	System-Generated Organization	Learner-Generated Organization	
		Cued	Uncued
Identification	12.98	14.11	12.49
Terminology	11.99	12.79	10.87
Comprehension	10.78	12.34	10.44
Problem-Solving	4.77	4.72	3.53
Drawing	13.54	14.56	12.07
Total Score	40.53	43.95	37.32

Covariate is pretest score

Table 2
Analysis of Covariance

	DF	Sum of Squares	Mean Square	F Value	Significance of F
Identification	2	35.86	17.93	2.69	.075
Terminology	2	48.63	24.31	1.73	.185
Comprehension	2	52.42	26.21	1.96	.148
Problem-Solving	2	24.98	12.49	3.58	.033**
Drawing	2	80.93	40.47	2.58	.083
Total Score	2	577.48	288.74	3.10	.051

Covariate is pretest score

** Significant at the .05 level

Table 3
Significance Levels
Post-Hoc Comparisons

	Control vs. Cued Organization	Cued Organization vs. Uncued Organization	Control vs. UncuedOrganization
Identification	.151	.026**	.518
Terminology	.480	.068	.318
Comprehension	.159	.063	.754
Problem-Solving	.921	.024**	.028**
Drawing	.395	.027**	.218
Total Score	.240	.015**	.267

Notes

1. Legend
   Control = System-Provided Organization
   Cued Organization= Learner-Generated Cued Visual Organization
   Uncued Organization = Learner-Generated Uncued Visual Organization

2. Covariate is pretest score

3. ** Significant at the .05 level

4. Not all analyses of variance are significant at the .05 level.